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## **Transferring Cutting-Edge Research to Museum Learning Environments: Science in the Making versus Ready-Made Science**

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### **Abstract**

School science differs considerably from the science of scientists. This is because in order to become teachable, science is taken from its original research context, deconstructed and reconstructed, and implemented in schools. While this transition is both necessary and inevitable, it may cause school science to become disembodied from its purpose or even obsolete. Accordingly, we suggest that museums are ideal places for the dissemination of cutting-edge science because they are not bound to school syllabi, they have immediate access to contemporary research, and they are already established as out-of-school resources. To examine this issue, we carried out a mainly qualitative study of the museum program DNA and Life. The program was intended to engage secondary school students in authentic, cutting-edge research. Through targeted analysis of observations, video recordings, interviews and questionnaires with eight participating classes, we identified characteristics of the program that contributed to the authenticity of its activities, and also characteristics that detracted from it. We discuss these characteristics with regard to the rapid transition of the programme's content from the world of science to the world of education, and offer our perspectives on their implications.

### **Problem**

The dissemination of natural sciences such as geology, biology, chemistry, or physics in educational institutions is based on the research disciplines that give them their name. However, there is rarely a one-to-one relationship between the way scientists produce science and the way learners re-produce that science in an educational setting. Rather, the science that is disseminated in educational institutions is the product of a deconstruction and reconstruction process (Duit et al., 2012) in which certain concepts and practices are selected according to societal, institutional, and pedagogical requirements and transformed into a more teachable form (Astolfi et al., 1997).

This transformation process, known as *didactic transposition* (Chevallard, 1991) is necessary and inevitable, but it carries with it certain risks. One clear danger is that of science education content becoming obsolete due to the period of latency (*didactic transposition delay*) between the acceptance of a new scientific finding by the scientific community and its introduction into science education contexts (Quessada & Clément, 2007). Another danger is that the process of transposition isolates science concepts and practices from the context that provoked their appearance - to the extent that they seem abstract and disembodied to learners (Brousseau, 2002). Both phenomena are detrimental to the widespread efforts to produce critical consumers of science (cf. Osborne & Dillon, 2008), and as a response, a range of instructional strategies have

been developed to construct school science situations that ensure authenticity, relevance, and personal engagement. However, another avenue worth exploring is the role of informal learning environments such as science museums.

We hypothesize that museums are ideal places for the dissemination of cutting-edge scientific research to science learners because of their autonomy, their authenticity, and their already-established relationship with schools. Their *autonomy* allows museums to provide their visitors with up-to-date science content with a rapid turnover (Van Praët & Poucet, 1992), since unlike schools, museums are not required to follow a set science syllabus. The *authenticity* of museums is not just due to their collections of scientific objects and specimens, but also to their role as places of on-going scientific research. And finally, many science teachers already use museums as out-of-school science resources, which puts museums in an ideal location for engaging learners in cutting-edge science.

The purpose of this study was to investigate the effects of a rapid didactic transposition of science from the world of research to the world of education by examining a museum-based school program that has the specific aim of providing students with opportunities to engage authentically in cutting-edge science. In this investigation, we focus on elements that pertain to the authenticity of the program's activities as perceived by museum educators, teachers and students. We ask: *What is the nature of the opportunities for and challenges to authentic learning experiences that manifest themselves in this particular cutting-edge school program?*

In the following **Procedure** section, we outline the school program and its educational potential. In the **Findings** section, we present key findings from an evaluation of the program. Finally, in the last sections, we discuss the implications of our findings for the science education community in general and for the members of NARST in particular.

## **Procedure**

The school program studied here, *DNA and Life*, is a pilot program for secondary school students in a natural history museum in Denmark. The program consisted of a day-long visit to the museum that included a practical laboratory session, a presentation and conversation with one of the scientists behind the featured laboratory method, and a conversation about the implications of the method with the fish curator, situated in the museum's aquatic animal collections.

### *Institutional relevance*

*DNA and Life* revolves around a new, ground-breaking research method for detecting species in freshwater streams and lakes by amplifying and sequencing DNA found in water samples. The method was developed by a research group at the museum in 2010-2011 (Thomsen et al., 2012). The immediate transposition of the method into an educational setting was piloted in the program *DNA and Life* in 2012. The pilot program was intended to provide students and teachers with an authentic alternative to in-school laboratory work, and to provide museum educators and potential funders a proof-of-concept.

### *Educational relevance*

The biology syllabus in Danish secondary school 'takes a point of departure in the scientific discipline, and is influenced by developments in modern biological and biotechnological research' (Ministry of Education, 2010). Because practical work is a central component of

scientific research, it has significance for secondary school biology students (cf. Kirschner & Meester, 1988). Criteria for successful practical work include a focus on the intellectual aspects of the work in addition to the practical aspects, the incorporation of inquiry-type activities, an appropriate level of difficulty, and transfer of responsibility (Abrahams & Millar, 2008; Hofstein & Lunetta, 2003; Reigosa & Jiménez-Aleixandre, 2007).

#### *Data collection*

In the present study, data was collected through observations and video recordings of the pilot program, questionnaires before, during and after the program, and interviews with teachers and students (see Table 1 for an overview). These data were collected to evaluate the pilot program's institutional and educational relevance as outlined above. Here, they are analyzed to assess how student outcomes are linked to an authentic learning experience, and to discuss the effects of a rapid didactic transposition.

**Table 1.** *Overview of collected data.*

<b>Respondents</b>	<b>Questionnaires</b> (Before, during and after)	<b>Interviews</b> (Before and after)	<b>Observations</b> (During)	<b>Video</b> (During)
Students (n=200)	118; 163; 139	6; 5	4 occurrences of the pilot program	4 occurrences of the pilot program
Teachers (n=5)	5; 5; 5	3; 2		
Educators (n=3)	-	-		

## **Findings and Analysis**

### *Museum educator perspective*

As the pilot program was meant to provide proof-of-concept, the museum educators' primary concern was to ensure that the method for treating water-samples in order to amplify traces of DNA was working. One immediate issue was that traces of DNA could hardly be detected after treatment. To remedy this, the educators elected to collect the water samples themselves, rather than letting the participating students bring their own samples as originally intended. Another decision was to postpone the introduction made by the scientist behind the method to allow more time for treatment of the samples. To compensate for the postponed introduction, the educators emphasized the cutting-edge nature of the tasks while students were doing them. This sometimes baffled the students:

Educator: You should be proud of yourself!

Student: Huh? It's really not that hard..?

To ensure that the procedure for amplifying and detecting DNA was followed to specification, the educators tended to micromanage the students. Ensuring the level of control necessary to assess potential challenges to the viability of the method may have been the educators' strategy to provide proof-of-concept, but unfortunately it also entailed the suppression of students' active participation.

### *Learner perspectives*

From the questionnaires, we did not find evidence that students' ideas about science changed. Still, there were strong indications that students enjoyed taking part in the pilot program,

primarily because they encountered science professionals who described their work memorably, and because they were thrilled by their privileged access to the non-public museum collection.

Regarding the experimental work, there were no indications that students engaged in an exploration of a piece of authentic science. As the quote above indicates, students had difficulties connecting their perception of the difficulty of the task with the notion that they engaged with research. One reason is that they were never allowed opportunities for intellectual exploration of methodological questions, and were instead kept to a strictly sequenced routine. During consecutive iterations of the laboratory exercises, we could observe how the museum educators gradually eradicated situations for potential contamination of the water samples by taking back responsibility even for mundane tasks – to the extent that the tasks became almost trivial.

We can trace this effect back to the museum educators' interest in removing obstacles or challenges to the method students were employing in order to make sure that viable results could be obtained.

#### *Teacher perspectives*

The authenticity of the pilot program DNA and Life was the stated reason the majority of the participating teachers chose to involve their students in the program; in part because they expected the authentic aspects of the program to motivate their students to learn biology. When elaborating their conception of authenticity, the teachers emphasized aspects such as engaging in a new, untested method, producing real data, working without a lab manual, and using real lab equipment with real samples. However, in post-program interviews, these criteria had subtly changed, and reflected aspects such as the uncertainty of gaining results from scientific inquiry.

#### **Contribution to the Science Education Community**

Our analysis of *DNA and Life* both contradicts and supports the notion that museums are ideal places for the dissemination of cutting-edge science research. Support is provided by the consistently high value teachers ascribed to the authenticity of the pilot program before, during and after it took place (although their criteria changed during the program), and by the consistently high level of enjoyment reported by students.

However, the gradual lessening of the assignment's requirements by the museum educators in order to avoid the participants' failure, the so-called *Topaze effect* (Brousseau, 2002), is problematic. We suggest that the issues that affected *DNA and Life* originate, fundamentally, from a failure to adequately define the pilot program's objectives: Was it intended as a way of introducing students to science-in-the-making with a corresponding focus on the processes (and uncertainties) of science, or was it intended as a way for students to acquire (proven) ready-made science in the production of real results (cf. Latour, 1987)?

We suggest both, or perhaps neither. The educators' concern was to ensure real results, by way of which they minimized the students' role in the process of doing science. When the production of real results failed, the activity lost its authentic purpose. A further readying of the science (e.g. ensuring the method was capable of providing viable results) for the students would have entailed a longer didactic transposition delay. Conversely, minimizing the didactic transposition

delay would demand a readying of the students to engage with possible methodological failure, which was not the case during *DNA and Life*.

The present study hints at both the challenges and the attractive aspects of implementing cutting-edge science into out-of-school education environments that focus on science-in-the-making. Cutting-edge scientific methods often are new enough that the uncertainties of how and why they work are still in question. This characteristic could be developed in museum programs, but not without deliberately emphasizing inquiry-type activities.

### **General Interest to NARST Members**

The Next Generation Science Standards (NGSS) represent a conceptual shift in performance standards and thus a shift in the ideals that drive science education and learning (NGSS, 2013). The vision is to direct student and teacher interest and motivation for teaching and learning science towards understanding how scientific knowledge is acquired and applied, and how science is connected through concepts and disciplinary core ideas. Teachers will now be expected to create coherent instructional programs that suit their particular students' requirements. It is likely that some of these requirements will concern cutting-edge science and science-in-the-making. This is why we must pause and reflect, for example, on what this means for teachers who wish to teach the reform through a shortening of the didactic transposition delay? It also means to stop and consider how teaching practice might change to help students gain contextual experience with cutting-edge science and at the same time attain Next Generation Standards performance expectations.

Here, we hypothesize that science museums are ideal venues for the dissemination and learning of cutting-edge science. From this perspective it seems likely that teachers and students to increasing degrees will look to these institutions to have their requirements for cutting-edge science met by participating in the making of science and creation of scientific knowledge. In this regard, this paper provides a cautionary tale, but also, it draws attention to a set of instructional strategies which resonate well with NGSS; strategies that teachers, evaluators, creators of instructional designs and museum management and curators alike will be likely to consider beneficial to their work:

- Engagement in the co-creation of science requires an explicit focus on the scientific practices and skills involved in the making of science.
- Engagement with a rapid didactic transposition of science in the making into ready-made science requires a substantial 'readying' of this science.

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